# North-West African Upwelling dynamics from physical and biological satellite observations

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## Objectives

1. Study the North-West African Upwelling dynamics in interplay between its spatio-temporal extensions and intensity.
2. Understand the nonlinear relationship between oceanic mesoscale structures and the primary production.
3. Contribution of coherent mesoscale eddies off the North-West African Upwelling on the open ocean.

## Introduction

- Eastern Boundary Upwelling zones include some of the most productive ecosystems in the world, particularly the North-West African upwelling which presents one of the world's major upwelling regions. North-West African upwelling is characterized by persistent and variable Upwelling phenomenon almost all around the year. Although it represents a small portion of the world's ocean surface, it is considered as one of the most productive regions of the world due to its high biological productivity and its impact on commercial fisheries.

## Data

Our work focuses on the North-West African Upwelling spans from $\mathbf{9.51°}N$ to $\mathbf{36.21°}N$ and $\mathbf{4.26°}W$ to $\mathbf{19.97°}W$.

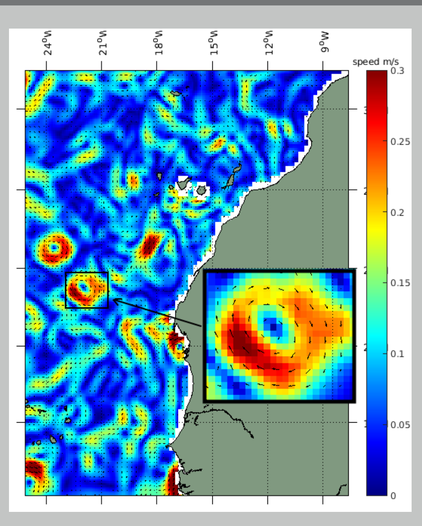



Figure 1: Sea surface velocity field in the NW-African Upwelling

- Throughout This work, we use various remotely sensed data:
  - Sea Surface Temperature (SST), provides a quantitative and synoptic overview of thermal characteristics in the ocean.
  - Chlorophyll-a concentration, provides an estimate of the live phytoplankton biomass in the surface layer.
  - Sea surface velocity field derived from satellite acquired sea surface height under the geostrophic approximation.
  - Sea surface wind from QuikSCAT.

## Upwelling dynamics in interplay between its extension and intensity

- Previous studies have addressed the problem of the automatic identification and extraction of the NWA Upwelling from SST images, However, these methods work partly in the southern regions of the upwelling system due to the high nonlinearity found in the upwelling distribution of temperature.
  - Here we have developed an automatic tool based on the Ekman transport, which allows us to overcome the problems faced in previous studies.
  - Based on this method, we proposed a novel Upwelling index which has several advantages: simplicity, computational efficiency and accuracy.
  - we have studied the spatio-temporal dynamic of the NWA Upwelling.
  - We characterized regions with different Upwelling properties.

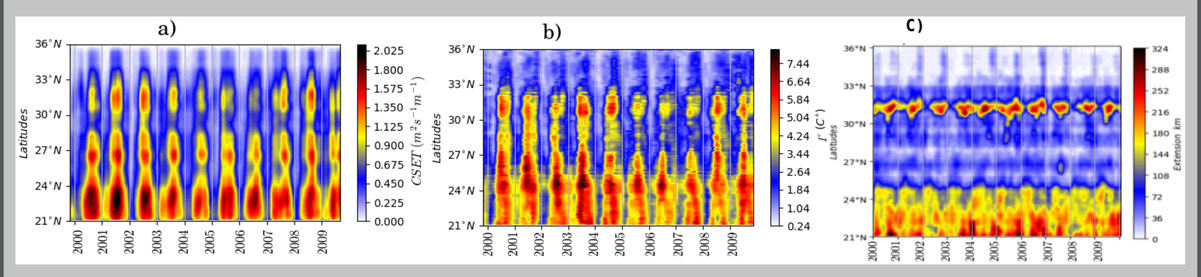
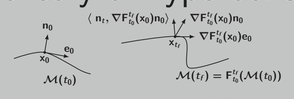



Figure 2: Space-time Hovmoller plot of the seasonal and interannual variability of: a) ICSET b) Upwelling index, c) Upwelling extension, between 2000 and 2009.

## Surface Mixing and Biological Activity in the North-West African Upwelling

Variational theory of hyperbolic LCS;



particles within LCS satisfy:

$$\mathbf{x_0} \in \text{LCS, if} \quad \langle \mathbf{n}_t, \nabla \mathbf{F}_{t_0}^{t_f}(\mathbf{x_0})\mathbf{n_0} \rangle > \left\| \nabla \mathbf{F}_{t_0}^{t_f}(\mathbf{x_0})\mathbf{e_0} \right\| \quad (1)$$

LCSs can be extracted from hyperstreamlines as segments $l_r$ satisfying:

$$\forall \mathbf{x_0} \in l_r, \quad \langle \xi_2(\mathbf{x_0}), \nabla^2 \lambda_2(\mathbf{x_0}) \xi_2(\mathbf{x_0}) \rangle < \mathbf{0} \quad (2)$$

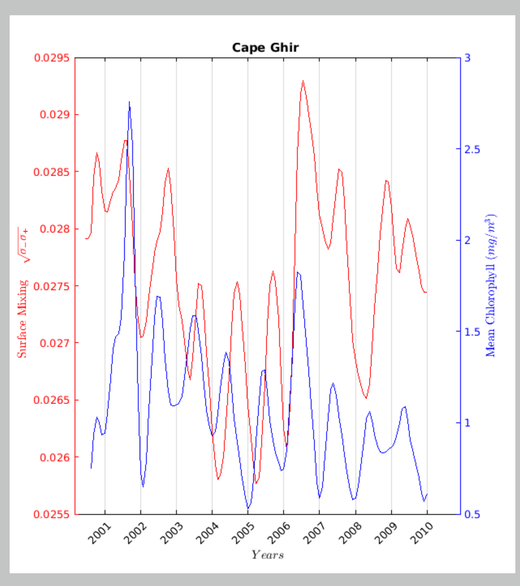



Figure 3: Interannual variation of the surface mixing versus the fronts chlorophyll concentrations.

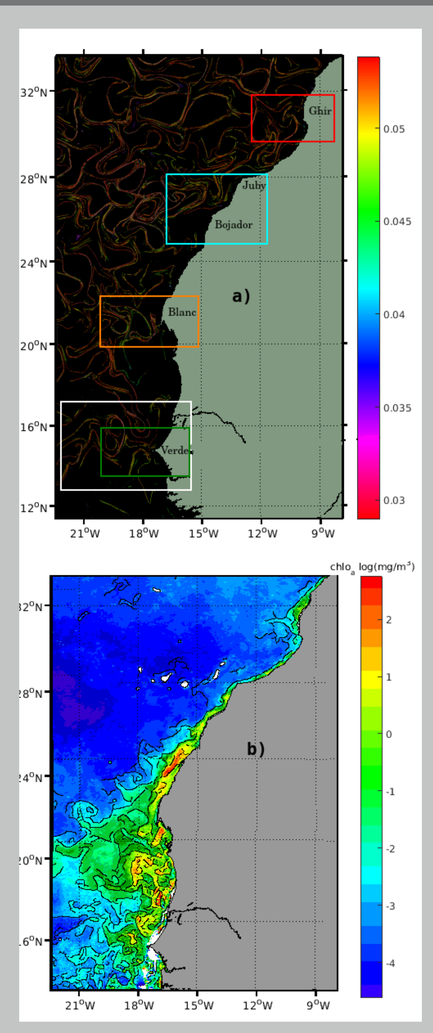



Figure 4: a) Hyperbolic Lagrangian coherent structures, b) Chlorophyll image with MSM fronts overlaid on top.

## Contribution of coherent mesoscale eddies off the North-West African Upwelling on the open ocean

- We have given an objective definition of Lagrangian vortices from particles trajectory [A. El Aouni, *et al.* Chaos].
  - We use this method to study the contribution of mesoscale eddies off NWA margin on the open ocean.

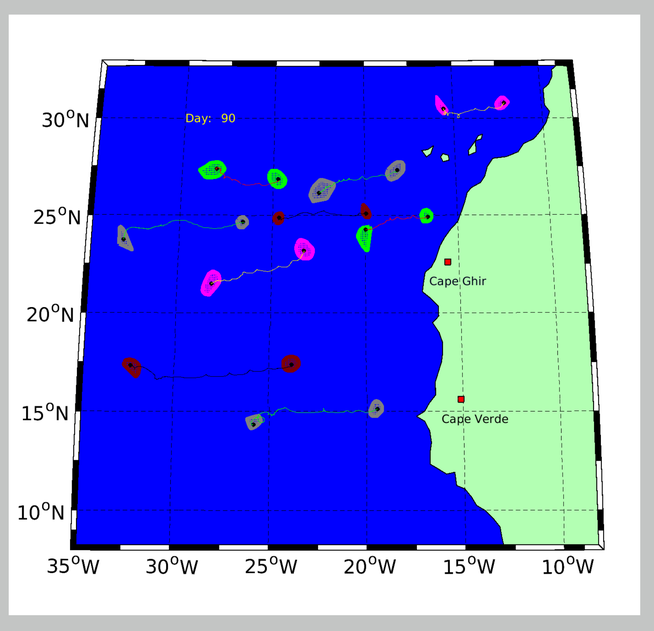



Figure 5: Eddies off NW African margin (under 90 days of Lagrangian advection).

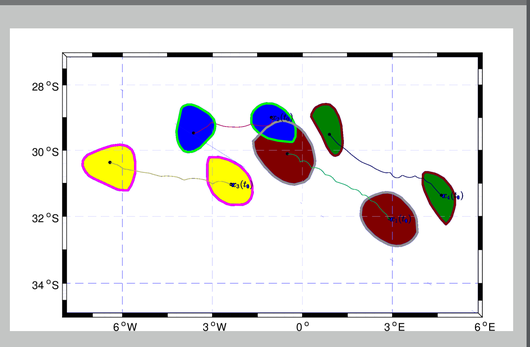


Figure 6: Coherent vortices and their centers at initial time (day 1) and final position (day 90) under Lagrangian advection.

- Under one year of simulation:
  - 36 eddies with lifetime of 90 days.
  - diameter from (70-140km).
  - total of 242516$km^2$ of surface water masses transported to the offshore
  - 13 eddies with lifetime of 180 days.
  - diameter under 100km.
  - total of 62715$km^2$ of surface water masses transported to the offshore

## References

- A. El Aouni *et al.* Segmentation, quantification and dynamics of coastal Upwelling using SST satellite images, submitted to transaction on geoscience and remote sensing.
- A. El Aouni *et al.* Surface Mixing and Biological Activity in the North-West African Upwelling, submitted to Geophysical research letters.
- A. El Aouni *et al.* Defining coherent vortices from paricles trajectories, submitted to American Institute of Physics, Chaos.

## Contact Information

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